Exploring the Illusion of Understanding in Small Transactive Memory Systems

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Abstract

People typically overestimate their ability to explain how artefacts and other complex phenomena work – this is known as the illusion of understanding (IOU). In an online experiment, we aimed to identify if an IOU occurs in both individuals and small transactive memory systems. Participants (N = 46, 23 pairs) completed the experiment at the same time as their self-selected partner. Individuals rated their own, partners', and combined knowledge of bicycles, on a scale of 1-7, before and after completing individual and collaborative tasks that drew on their bicycle knowledge. The strength of relationships between pre- and post-task individual, partners', and combined ratings of knowledge and number of errors made on the individual and collaborative drawing tasks were analysed. Individuals' pre-task ratings (M = 4.74) were higher than their post-task ratings (M = 4.39, $t(45) = 2.27$, $p < .001$). People rated their own personal knowledge (before the task) as lower than they rated their collaborative knowledge (after the task), the difference between means was $M = .65$, $p < .001$. Contrary to predictions, there was a stronger relationship between individual pre- and post-task ratings ($r = .83$, $p < .001$) than for individual pre-task and collaborative post-task ratings ($r = .60$, $p < .001$) ($z = -3.26$, $p < .001$). The relationship between individual pre-task ratings and collaborative performance errors ($r = .19$, $p > .05$) was significantly stronger than the relationship between individual pre-task ratings and individual performance errors ($r = -.23$, $p = .066$) ($z = -1.53$, $p = .062$). Results showed an IOU in individuals but not in small transactive memory systems. Future research could investigate how individuals make their ratings and inspect the distribution of pre- and post-task ratings.

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Exploring the Illusion of Understanding in Small Transactive Memory Systems

A common phrase heard when working in small teams is, “two heads are better than one”. Is this true? Are two heads better than one? This project aims to address this question by investigating how knowledge is stored and evaluated within individuals and small groups.

Two fields of literature, which appear disconnected on the surface, will be drawn on to provide background and theoretical predictions. The first area of literature is that about the knowledge illusion. An illusion of knowledge occurs when people feel they understand complex phenomena with greater precision, coherence, and depth than they do. Currently, there is strong evidence to support the existence of an illusion of knowledge in individuals (Alter et al., 2010; Gaviria et al., 2017; Justin & David, 1999; Keil, 2003; Keil, 2012; Lawson, 2006; Meudell et al., 1992; Mills & Keil, 2004; Putnam, 1975; Rozenblit & Keil, 2002; Sloman & Fernbach, 2017; Wilson & Keil, 1998; Wilson & Keil, 2000; Ylikoski, 2017; Zeveney & Marsh, 2016). Research in this area suggests but has not confirmed, that working in teams allows individuals access to information that is outside of their areas of expertise, and may be an effective way to reduce the illusion of knowledge (Barnier et al., 2018; Basden et al., 1997; Rozenblit & Keil, 2002; Wilson & Keil, 1998). Currently, there is little to no evidence to support this theoretical prediction.

The second area of literature drawn on in this thesis is that on transactive memory. Transactive memory theoretically describes “the process by which benefits for memory can occur when remembering is shared in groups or dyads” (Harris et al., 2008, p. 267). This process occurs within a set of individuals who can develop shared systems of encoding, storage, and retrieval to access information held by others. During the development of these strategies, individuals can either develop strategies that can help or hinder this process. It is this access to

other members of the transactive memory system's areas of expertise, that is the key link between the two areas of literature.

Both areas will be discussed in more detail below. The overall aim, of the project, is to support the current findings of the literature in both areas and use evidence to support the theoretical links between these areas of literature. While completing the overall aim of the research, a secondary aim is to identify if individuals can recognise the limits of their groups' knowledge more accurately than they can recognise their own.

The Knowledge Illusion

From a field founded by Wilson and Keil in 1998 with their paper *The Shadows and Shallows of Explanation*, the knowledge illusion area has grown and now has a large volume of research with an impact across many fields. Beginning with a paper drawing on past philosophical efforts to provide a conceptual analysis and pinpoint the core of explanation, Wilson and Keil (1998) created an interdisciplinary investigation into explanations and understandings. Within the field of psychology research on the topic has spanned from development to politics, investigating the illusion of knowledge within individuals and how this can be manipulated by altering information presented.

A brief skim of the literature would lead you to believe that two distinct areas had been formed. On the face of it, these areas appear isolated, however, Wilson and Keil (1998) identify and explain the differences between both the Illusion of Understanding (IOU) and the Illusion of Explanatory Depth (IOED) in their original paper. Under strong caveats, Wilson and Keil (1998) concisely conclude that the distinction between an IOU and an IOED occurs due to people being unable to explain something they do not understand. When explaining this distinction further, it

was identified that understandings require knowledge and prediction which are acquired through inference and memory. Understandings are primarily implicit and unarticulated until they are required when an attempt to provide an explicit explanation of their knowledge is made by an individual. Explanations, on the other hand, are the product of something we do either individually or collectively during our interactions with the world, these are conceptually richer and are a better way of making sense of the underlying structure of the world. Typically, explanations are a successful attempt to increase understanding, therefore are something we all use. These are created by experts, with individuals being unable to remember the complex dynamics of explanations created by experts. "Explanations serve to buttress our overall conceptual frameworks for interpreting and making sense of the world around us." (Wilson & Keil, 1998)[1].

Often individuals will believe that their understandings and explanations are pretty good, but, unless the individual is an expert in the field this is not normally the case. This difference in the perceived level of knowledge and the actual level of knowledge is an illusion of knowledge. It is not until they are asked to provide an explicit explanation of their understanding that they may become aware of this illusion. Up until this point, individuals are oblivious to the shallowness of their implicit understanding. Implicit knowledge lacking in depth is not unusual, occurring more commonly than not (Wilson & Keil, 1998). During the process of forming explicit explanations, individuals may become aware they are missing vital pieces of

[1] Wilson and Keil (1998) also state that prediction is different from both understanding and explanation. Explanations helping to sharpen individuals' abilities to perceive and respond to events in the future, but do not provide individuals with the ability to make precise predictions about what will occur more than a moment or two into the future. However, prediction is not a focus of this thesis.

information as well as arbitrary details required to complete their explanations (Rozenblit & Keil, 2002; Wilson & Keil, 1998).

An illusion of knowledge can be described by the idea of a theoretical abyss. "A theoretical abyss exists between our ability to provide limited explanations that suffice for the purposes at hand and the possession of corresponding, detailed theoretical knowledge that would allow us to provide more satisfying richer explanations." (Wilson & Keil, 1998, pp. 148-149). These limited explanations, as a result of a lack of detailed theoretical knowledge, are often described as the shallows of explanation. Arguments presented by Wilson and Keil (1998) conclude that there would be no theoretical abyss if the shallows of explanation were owed to something other than the absence of such theoretical knowledge. Therefore, all social explanations, which suggest contextual or social features affect a person's ability to give explanations, and their variants presented as alternatives to the theoretical abyss hypothesis are false.

For a person to avoid an illusion of knowledge, due to the theoretical abyss, they require access to a web of knowledge. These webs of knowledge are typically held within a community, and to access the web of knowledge they must be a part of the community which holds it. The term web of knowledge refers to a network of detailed theory and information from subject matter experts but can be accessed by experts and laypeople alike. Typically, however, laypeople miss the depth of information stored in the expert-held webs of knowledge. It is this depth of knowledge held and accessed by experts which helps them avoid a theoretical abyss. Both individuals and experts can hold and access webs of knowledge that can eliminate a theoretical abyss in specific areas, and in small bursts across subject areas. It is important to note that individuals are unable to maintain an in-depth web of knowledge across all aspects of life.

An illusion of knowledge is likely to occur when an individual's web of knowledge is incomplete. To navigate this inability individuals regularly rely on the expertise of others in their community to fill the gaps in their understandings and explanations (Wilson & Keil, 1998), an area explored by Sloman and Rabb (2016).

To explain how individuals can avoid an illusion of knowledge through the use of a web of knowledge held with a community of experts, Wilson and Keil (1998) borrow the idea of the division of linguistic labour from Putnam (1975). The division of linguistic labour was described by Putnam (1975) using two general groups within the population, linguistic experts and laypeople.

A well-known example by Putnam (1975) used to explain the distinction between laypeople and experts uses the word, or concept, of water. Every day, laypeople use the word water without acknowledgement of or knowing that the word water refers to the specific kind of molecules and properties water has. Laypeople can communicate both with other laypeople and experts in linguistics, without having the depth of knowledge that experts have. Linguistics experts hold an in-depth web of knowledge that laypeople are missing. When collaborating with laypeople, they can share this knowledge to fill gaps in the layperson's understanding and explanations (Putnam, 1975). Wilson and Keil (1998) propose a similar theory to describe how groups can cooperate to avoid the knowledge illusion using the similar term they coined - the division of *cognitive* labour. Rozenblit and Keil (2002) note that when an individual becomes aware that they are a layperson rather than an expert, they are less inclined to overestimate what they know as they are aware of the web of knowledge around them and are more likely to recognise the shallowness of their knowledge.

Individuals can make it through their day-to-day life with incomplete explanations unaware of the shallowness of their knowledge. With a shallow understanding of everyday concepts, laypeople can explain general ideas and complete everyday tasks without the need for the deeper details required when providing full explanations. These surface details are connected, within a web of knowledge, to the deeper levels of knowledge readily and easily accessed by experts. Wilson and Keil (1998) discuss that this shallow knowledge with links into the web of knowledge is an efficient and adaptive way for us to function and protects individuals from needing to be an expert at everything.

Reading between the lines, the founding literature in the field strongly suggesting that an illusion of knowledge could be avoided through collaboration, research in the area has had a clear individualistic focus. Although collaboration between two people is not the same as having access to the web of knowledge available to a community, two people working together on a task is closer to a community of knowledge than one. This individualistic focus has meant that there has been no direct evidence provided to support the theoretical ideas of Wilson and Keil (1998) relating to the division of cognitive labour. Development in the field has avoided investigating communal knowledge in favour of manipulating individual perceptions of communal knowledge as is seen in the likes of Sloman and Rabb (2016) and Gaviria et al. (2017).

Empirical Research examining the Illusion of Understanding.

Experimental research in the fields of the IOU or IOED tends to adopt a particular structure. Firstly, individuals are asked to either make a rating of their knowledge of a phenomenon (e.g., artefact, policy, theory), typically on a Likert-type scale. They are then asked to demonstrate their understanding, for an IOU, or try and create an explanation, for an IOED, of

the phenomenon. Individuals then re-rate their understanding or knowledge. An IOU or IOED is demonstrated when the re-ratings are lower than the original ratings. Examples of phenomena used include bicycles, ballpoint pens, how toilets are flushed, history, economics, and political policies (Gaviria et al., 2017; Keil, 2003; Lawson, 2006; Sloman & Rabb, 2016).

Sloman and Rabb (2016) conducted four experiments investigating the community-of-knowledge hypothesis – that people fail to distinguish their own knowledge from other people's knowledge. They asked individuals to rate their understanding of novel natural phenomena (e.g. new rock discovery or cave formation) both when experts understood a phenomenon and when they didn't. In both conditions, no actual explanatory information was provided. Their findings showed that when individuals believe experts understand a phenomenon their sense of their own knowledge increased when they had confidence in their ability to access this expert knowledge.

Gaviria et al. (2017) conducted an experiment examining the relationship between the social desirability of knowledge and the magnitude of the IOED. Their results showed that people were more likely to overestimate their knowledge and have a stronger IOED when the knowledge being explained is perceived as socially desirable. Both pieces of research emphasise that the knowledge illusion is impacted by social factors.

Other research covers a broad range of fields and has investigated an illusion of knowledge in areas from the political domain (Alter et al., 2010) to cognitive development (Mills & Keil, 2004). Across the research, a link between the knowledge illusion and construal level theory was identified. According to construal level theory, individuals construe or represent the world along a continuum from abstract to concrete. Abstract representations tend to capture the essence of a target with a broad focus on its general features such as people do not need to understand how the earth quakes to recognise the consequences of an earthquake. Concrete

representations focus more closely on a target's specific features or details such as how the earth quakes during an earthquake. Findings from this research found that individuals commonly adopt a more abstract lens when a question demands a more concrete approach.

Alter et al. (2010) also showed that an illusion of knowledge occurs in the political domain. Findings across multiple studies found that individuals regularly adopt a political opinion and stance while being susceptible to an illusion of political sophistication. An illusion of political sophistication occurs when voters know just enough to hold basic conversations about rival candidates. They know enough to feel informed at an abstract level but not enough to recognise they are under-informed at a concrete level, and are able to identify the policies of a candidate, but are unable to give details about the policies (Alter et al., 2010). When asked, individuals were unable to explain their preferred candidate policies in as much depth as they believed they would be able to. The research of Alter et al. (2010) demonstrated a robust illusion of political sophistication.

Children are not immune to an illusion of understanding and have been seen to utilise the division of cognitive labour in a community. A substantial amount of research is beginning to investigate the illusion of knowledge with children and young people. One of these pieces is the work of Mills and Keil (2004) who showed that by the second grade most children demonstrate an illusion of knowledge: this is the first of two main findings drawn from this work. A second finding was that although an illusion of knowledge was seen in second graders when they were asked how to use the technology, no illusion was seen when they were asked to demonstrate their knowledge. Keil (2012) explains that young children and toddlers are well known for asking "why" or "how" questions which are used to build a sense of causal patterns that exist above the level of mechanisms. This is a way for young children to avoid being

overwhelmed by the mechanistic details, that are needed for full explanations, by relying on the contents of other minds. This shows that even the youngest members of society display behaviours that are supportive of the theory of distributed cognitive labour (Wilson & Keil, 1998).

Although this research has fascinating findings when individuals are removed from their community and web of knowledge, research in which participants are connected to their community and web of knowledge and is more like the environment outside of the laboratory. An environment less like a laboratory environment may provide individuals access to the web of knowledge individuals have access to during their everyday lives, this could provide valuable insight about how webs of knowledge are accessed and utilised by individuals everyday. A primary focus of this research was to investigate the knowledge illusion in a more ecologically valid environment than that seen in the research that has occurred so far. It is well known that results found in the laboratory do not always translate to the world outside of the laboratory as there are a number of factors that are not available in the lab that could be important in this research. Research that accounts for these factors may more practically applicable in real-world examples. Two pieces of research in the area played critical roles in the current research.

Knowledge Illusion Literature Influencing the Current Research Development

The first of these two pieces of research which assisted in the development of this project is the work of Rozenblit and Keil (2002). This work supports the thinking of Wilson and Keil (1998) finding that laypeople are rarely asked to explain many of the things that they believe they understand. Rozenblit and Keil (2002) conducted a series of 12 studies, the first six confirmed the existence of the knowledge illusion across several populations. Studies seven to

ten showed the knowledge illusion's nature by tracking the magnitude of the illusion across several different domains – facts, procedures, narratives, and natural phenomena – of knowledge finding that devices and natural phenomena reported large drops in knowledge estimates when people are asked to make their knowledge explicit whereas procedures and narratives showed no drop. The remaining two studies examined factors that influenced the extent of the illusion and showed significant differences in desirability ratings across the domains of the study. This thorough research provided confidence in the existence of the knowledge illusion and due to the number of studies conducted a solid grounding from which to base predictions for the current research. Rozenblit and Keil (2002) focused on the frequency of *individuals* producing explanations. One reason provided for individuals' shallowness of knowledge and limited ability to explain how artefacts work, even when many of the working parts of the system are visible, is the frequency of explanations being produced (Rozenblit & Keil, 2002). Explanations infrequently being produced is particularly common in laypeople where these understandings and explanations are uncommonly offered for phenomena that they believe they understand. Laypeople have no reason to doubt their naïve intuitions that they can explain the world they live in well. In comparison experts, or those in positions where they are regularly explaining phenomena such as teachers or writers, are less likely to have an overestimation of their knowledge (Rozenblit & Keil, 2002).

The second of the two pieces that assisted in the development of the thesis is the work of Lawson (2006). She investigated the knowledge illusion by asking people to draw the key components of a bicycle. She showed that people overestimated their pre-task ratings and demonstrate how bicycles function. Lawson (2006) found that when asked to complete a schematic drawing of a bicycle (see Figure 1), participants regularly made errors that would

impact the functioning of the bicycle, shown in Figure 2. There were three types of errors that could be made: errors locating the position and shape of the frame; chain; or pedals. Examples of errors that were made included connecting the front and back wheels with the chain, making the bicycle impossible to steer (Lawson, 2006). Typically, knowledge is weak for everyday objects as a result of this information not being useful when using practically these objects (Rozenblit & Keil, 2002), however, in this research, this everyday knowledge is critical for the use of the bicycle.

Figure 1.

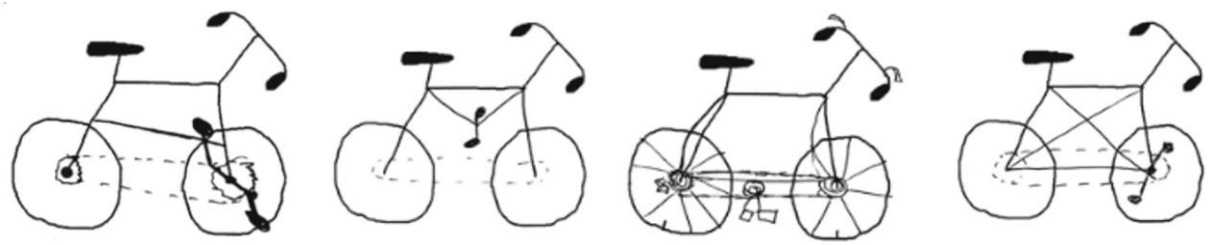
Schematic bicycle drawing for individual and collaborative free drawing tasks.

Reproduced from "Lawson, R. (2006). The science of cycology: Failures to understand how everyday objects work. Memory & Cognition, 34(8), 1667. https://doi.org/10.3758/bf03195929".

Figure 2.

Examples of errors made in schematic drawing free drawing tasks.

Reproduced from "Lawson, R. (2006). The science of cycology: Failures to understand how everyday objects work. Memory & Cognition, 34(8), 1667. https://doi.org/10.3758/bf03195929".



Interestingly, Lawson (2006) found that schematic drawing errors still occurred when the participant was an expert (a person who regularly cycled). In a third experiment, Lawson (2006) found that cycling experts and those that rode a bike a minimum of once a week made fewer, but did not eliminate, errors than the nonexpert groups tested in the earlier experiments. These findings support the theoretical predictions of Wilson and Keil (1998) that knowledge is held by those who are experts in the field.

In sum, empirical research supports the idea that people are unable to identify where their knowledge ends, and that of others begins. This raises the question, why does the research on the knowledge illusion focus on exploring individuals' shallowness of knowledge rather than their ability to access the knowledge that is distributed across the members of a cognitive community? Thus, it is useful to examine research that explores how people access knowledge and make judgements about that knowledge when part of a group. The next section examines a well-established approach to this idea known as Transactive Memory Systems. After describing the key findings and principles, it will be explained how the lessons of Transactive Memory System research can be usefully integrated with research on the Knowledge Illusion.

Transactive Memory Systems

Wegner et al. (1985) described a transactive memory system as a set of individual memory systems connected by communication. The transactive memory system research was developed as the theory of the group mind fell into disfavour during the behavioural revolution in psychology (Wegner, 1986).

Group mind theory also exists in a similar area of research. This is a simple theory to explain the otherwise complex phenomena of the behaviour of crowds. Groups, or crowds, can in certain situations become a unified entity that acts as if guided by a single mind or conscience (American Psychological Association, 2020).

Unlike group mind theories, transactive memory draws on the advances in the study of the individual thinking process and on the similarity between the mental processes of the individual and the processes of the group. The differences between group mind theories and transactive memory systems highlights the importance of communication. It is through this communication that individuals can access information held by others which they do not have themselves. Transactive memory systems see individuals functioning as external storage for other members of the group which needs to be connected to rather than as an internal system that is always connected and accessible.

Transactive memory systems are formed in both formal and informal settings. The formation of transactive memory systems occurs when individuals learn something about the expertise of another member of the system. Key to the strength, success, and efficiency of the new system is the accuracy of the information gathered during this process (Wegner, 1986). Typically, the accuracy of the information about other members of the group's expertise improves over time. This explains why long-standing transactive memory systems are more

efficient than new systems, as the assumptions about a person's expertise have been refined (Wegner, 1986).

In well-integrated transactional memory systems, the members are often able to perform better than they would as individuals as a result of the collaborations with other members of the system (Wegner, 1986). The key to a successful transactive memory system is the group's encoding of knowledge and information, communication about where the information should be stored, and retrieval of the stored information (Wegner et al., 1985). Encoding most commonly occurs incidentally, without individuals intentionally setting out to remember specific information, during shared experiences where members discuss and rehash the new information from an external source before deciding where it should be stored (Wegner, 1986; Wegner et al., 1985). Occasionally this is not a simple process and group members need to be assigned specific details to remember. For example, if there is an expert in a field the information is related to, this individual will be information that is at least partly related to their field of expertise. Experts do not always exist within transactive memory systems. In these situations, a process of negotiation occurs to decide where to store the information. If the system is formally constructed, such as teams formed in a workplace, the information will likely be assigned to an individual whereas, informal groups will often assign the individual who first encountered the information as the location of where the information should be stored (Wegner, 1986). If a transactive memory system is to be successful, information storage will not be left to chance (Wegner, 1986).

When information is required, recall from within the transactive memory system can occur when the stored information is required. Information is retrieved either spontaneously or through a complex interplay and discussion that occurs between individuals to retrieve

information from multiple sources or individuals. The retrieval process begins by determining the location of the desired information. If only one person holds the information this process is simple, and the information can be easily retrieved. This occurs most commonly when information is stored by an expert (Wegner et al., 1985). When information is held by more than one individual, a collaborative effort and communication are required to locate and retrieve the information. A process of cueing to retrieve pieces of information from multiple members occurs. It is this collaborative process that makes transactive memory systems different from individual memory retrieval as information does not solely reside in one person's head (Wegner, 1986).

Empirical Research examining Transactive Memory Systems

Research into transactive memory systems in couples in long term relationships has supported the idea that systems more than three months old draw on the expertise of the members of the system. Giuliano and Wegner (1985) asked couples who had been seeing each other exclusively for a minimum of three months to remember 64 items, with each item drawing on a different area of expertise. Items included food items and history items. Individuals were asked to review the areas of expertise and indicate if they, their partner, neither, or both would be the expert in each area. Each person was given one minute to remember 4 items and then pass them to their partner to remember before receiving another set of items. Unsurprisingly, the strongest effect found was for individuals' remembering items from their own area of expertise, but a clear transactional phenomenon was also found. This transactional phenomenon showed that participants who encountered the information first were responsible for the information and

were also responsible for this topic. These people recalled more items related to that topic when neither member of the couple were experts in the area (Giuliano & Wegner, 1985).

Harris et al. (2011) explored the dynamics of transactive memory systems in long term married couples. They also found that while some methods of interaction, such as conflicting individual strategies, were associated with better recall while others were associated with collaborative inhibition. Collaborative inhibition is one possible explanation for why collaborative groups recall less than nominal groups, the sum of the same number of individuals working alone (Basden et al., 1997; Basden et al., 2000; Harris et al., 2011; Weldon & Bellinger, 1997). The results found by Harris et al. (2011) when investigating collaborative inhibition contradict the findings replicated in previous studies, that collaborative groups recall less than nominal groups (Basden et al., 2000; Harris et al., 2011; Harris et al., 2008; Weldon & Bellinger, 1997). Harris et al. (2011) have, however, supported the original theorising of Wegner et al. (1985) that collaborative groups will remember more than nominal groups, with the results of Harris et al. (2011) showing that there are methods of communication, particularly the use of shared strategies, that are more effective than others. Collaborative facilitation has been found in studies conducted by Meade et al. (2009) and Harris et al. (2011) showing that collaborative groups can recall more than nominal groups consistent with the predicted benefits of transactive memory. This occurs when individuals possess slightly different pieces of information relevant to a particular topic and, through a process of cross-cueing – where the recall of one piece of information triggers the recall of another piece of information from another member of the group, can access information which allows the group to produce memories that no individual could recall alone (Harris et al., 2011).

Aspects of interaction associated with better collaborative recall show that collaborative inhibition is not an inevitable outcome of transactive memory systems (Harris et al., 2011). This study aimed to examine the social influences on memory in groups with a shared history, participants were asked to remember a range of stimuli from word lists to personal history and shared memories. The focus was on the level of detail and depth of collaborative information recall during an interview. From the data collected by Harris et al. (2011), one thing appears important for the success of the retrieval of information in pairs – a shared retrieval strategy. In some cases, individual strategies can be disruptive to the performance of the collaborative system and cause inhibition in recall, but this is not always the case. For some couples, recall strategies that are different can result in one-member cueing additional information from another. An example of this cueing includes situations where one individual in the system mentions a piece of information that in turn triggers another member of the system to remember a further piece of information. One couple in the Harris et al. (2011) study used actions to trigger the memory of items like a triangle to cue the recall of a tent. What appears to be more important is the presence or absence of a group level strategy that coordinates recall and capitalized on the relative knowledge and skill of individual group members (Harris et al., 2011). The importance of knowing the skills of team members was brought to light in Wegner et al.'s (1985) original work.

Reviews of the transactive memory literature have begun to appear, with Huebner (2016) providing an in-depth review. He calls for more research to be done to demonstrate that the research is showing cases of transactive memory systems in action. A further review of the literature conducted by Barnier et al. (2018) also calls for more research using an interdisciplinary framework for future research on transactive memory in small groups. Both

reviews advocated for future research to focus on small intimate groups. The relevance of the transactive memory field in future research is also considered by both reviews with Barnier et al. (2018) concluding that the area remains as relevant as it was when it was introduced and is well placed to contribute to the understanding of the lives of individuals and groups.

Linking the Research

Two distinct areas of research have been discussed. The first, examining the knowledge illusion, the existence of which has been strongly supported in individuals. The second, looking at transactive memory and how knowledge is shared between small, formal, and informal, groups.

There is scope in both the knowledge illusion and transactive memory literature for further research, with a specific focus on the division of cognitive labour, discussed in the transactive memory system and knowledge illusion research, being applied to further research in the knowledge illusion area. The connection of these two areas would allow for the exploration of an illusion of understanding in transactive memory systems.

Existing theory and research do not provide any real clue whether an illusion of knowledge might occur in a transactive memory system. Therefore, there is value in research to examine if this is the case. There is potential that an illusion of knowledge will not be seen as a result of knowledge judgements implicitly assuming the presence of a transactive memory system. Individuals have become adjusted to being linked to a transactive memory system and having access to the webs of knowledge held by these. When individuals are not removed from their transactive memory systems and webs of knowledge, as happens when the individual illusion of knowledge is assessed, their assessments of their knowledge should be more accurate

than when they are assessed without access to this knowledge. The present study aimed to test the idea that IOUs are a consequence of our adaptation to the knowledge of objects being held in a socially distributed cognitive system.

There are several practical applications for this research. Primarily, there is potential that this connection may be informative for further understanding how groups or small teams' function in situations allowing team or small group managers to more accurately assess the capabilities of the team or teams they are managing.

Overview of Present Research

The present research aims to form a connection between the literature in the areas of the knowledge illusion and transactive memory systems and to test the idea that IOUs are a consequence of our adaption to the knowledge of objects being held in a socially distributed cognitive system. It also supports the calls for future research in these areas.

It will draw on research in the knowledge illusion and transactive memory fields to further support the theoretical predictions of Wilson and Keil (1998) with the insights into the division of cognitive labour found in transactive memory systems theory (Wegner, 1986). A link between these two areas of research would provide a deeper understanding of how small groups understand their individual and collective knowledge. Through exploring this, we hope to assess an individual's ability to accurately identify the limits of the knowledge they hold and the knowledge of their transactive memory system. Theoretically, individuals are accurate with their own knowledge than their transactive memory systems.

Specifically, we aim to replicate the findings of Lawson (2006) and demonstrate an IOU in our sample by investigating the level of detail and accuracy of the information they have by

conceptually replicating Lawson's 2006 study where she asked individuals how much they knew about bicycles work. These data will be collected through stimuli which have will have no support from another member within a transactive memory system. We also aim to examine the IOU in small transactional memory systems using an adaption of the stimuli used by Lawson (2006). This will be conducted by allowing pairs to collaborate on selected tasks from Lawson's study. Finally, we hope to examine the changes in how individuals assess their level of understanding as individuals and as part of small transactive memory systems pre- and post-task.

Primary Hypotheses

The primary hypotheses for the project are as follows, with the first three looking at self-ratings of understandings. Firstly, it is hypothesised that individuals' pre-task ratings of their knowledge will be higher than their post-task ratings for the individual task. This will show if an IOU is present in the sample population.

It is also hypothesised that individuals' pre-task ratings of their knowledge will be closer to the post-task ratings of the collaborative task than the post-task ratings of the individual task. If this is seen in the results this will be consistent with the idea that individuals are unable to identify the limits of their knowledge and their initial ratings are a reflection of their knowledge if they had access to the web of knowledge within their transactional memory system. If this is not seen it will show that individuals are identifying the limits of their knowledge when removed from their transactional memory system and are under no less of an IOU when completing the task collaboratively than individually.

It is also hypothesised that the relationship between pre- and post-task ratings will be strongly correlated for the individual-collaborative (I-C) relationship than for the individual-

individual (I-I) relationship. Pre-task ratings are the ratings individuals are completing before they are completing the schematic drawing task. This is an individuals' first thought about their knowledge of bicycles. Post-task ratings are the ratings individuals are completing after they have completed the schematic drawing task. This is an individuals' thoughts about their knowledge once they have been asked to use their knowledge about bicycles. When making pre- and post-task ratings individuals are making two important assessments at each stage – individual and collaborative. These are ratings of their believed Individual and then what they believe their knowledge would be when working with their partner which is their collaborative rating. If the first correlation between the Individual pre-task and the collaborative post-task is stronger than the second correlation between the Individual pre- and post-tasks it will show that individuals' variation in self-ratings of understanding is more closely related to their collaborative abilities than their abilities. If the first correlation is not stronger than the second, this will show that the variation in individual pre-task ratings is more closely related to their performance than their collaborative performance.

The final primary hypothesis is that the relationship between the pre-task rating and performance (errors) will be stronger for the Individual pre-task rating and collaborative performance errors (I-C) than the individual pre-task rating and individual performance errors (I-I) correlation. If the first correlation of the pre-task collaborative rating and the collaborative free drawing errors is larger than the second correlation of the individual pre-task rating and the individual free drawing errors this will show that the variation in individual drawing errors is more related than collaborative drawing errors to their pre-task ratings.

Exploratory Hypotheses

The exploratory hypotheses for the project are as follows. It is hypothesised that pairs who have known each other for longer will do better on the collaborative tasks than those who have known each other for a shorter period. If this is seen this will support Wegner (1986) claims that the length of time a transactive memory system has been operating affects the accuracy of the transactive memory system. If the results do not support this, there will be no evidence within this data that the length of time a transactive memory system has existed impacts its efficiency and accuracy.

It is also hypothesised that relationship length will moderate that I-C relationship – that is people's self-ratings of their collaborative knowledge will be more strongly related to their collaborative performance the longer they have known the person they are collaborating with. This would show that the longer a transactive memory system has existed the better defined and identified the limits of the systems knowledge are. If this is not seen this would show that transactive memory systems are not reliably improving the longer they exist for.

Finally, it is hypothesised that owning a bike will moderate the I-I relationship – that is individuals self-rating of their knowledge will be lower for those who do not own a bicycle than those who do own a bicycle. This would show that individuals' self-ratings of their knowledge are impacted by individuals' perceived level of familiarity with the object. If this is not seen individuals are assessing their knowledge without considering familiarity.

Method

Participants

There were two methods used for the recruitment of participants for this research. The first method used was contacting individuals either through knowing the researcher, the Massey University Extramural Facebook page or those enrolled in a psychology paper at Massey University during the first semester of 2020. Each participant recruited through contact by the researcher was required to recruit a partner to complete the experiment with them. Both participants received a small reimbursement for their time.

Forty-six participants were recruited for the research, of this, 23 participants were recruited by the researcher and 23 were the participant recruited partners. These recruited participants and their partners formed 23 small transactive memory systems. All participants were required to meet the following criteria to be eligible to participate. They were required to (a) be at least 18 years old, (b) have known each other for a minimum of three months and (c) have access to individual laptops or computers. The 23 small transactive memory systems contained 16 males, 29 females and 1 participant who identified as neither male nor female. The age of participants ranged from 19 to 73, with a mean age of 29.93 years and a median of 28.5 years (SD = 9.181 years). Educational achievement in the sample population was varied, with data which showed that 4.3 percent had not completed high school at level 3 or equivalent, 28.3 percent of participants had a high school education, 15.2 percent held a certificate or diploma, 34.8 percent holding a minimum of a bachelor's degree and 17.4 percent holding postgraduate qualifications. The vast majority of the participants were able to ride a bicycle with only two participants being unable to ride a bicycle. Only 18 participants (39 percent) currently owned a bicycle.

All small transactive memory systems had existed for a minimum of 3-months, with a reported length ranging from 4-months to 540 months (45 years) with a mean length of 116.96 months (9.75 years) and a median of 54 months (*SD* = 129.39 months). Between partners occasionally there was a small amount of disagreement in the reported number of months they had known each other. Pairs with large disagreements in the length of their relationship were discarded as a result of meeting other exclusion criteria. Other disagreements in relationship length became irrelevant as pairs were placed in one of four groups depending on the length of their relationships. No included pairs reported differences which would have placed them in separate groups. Pairs were required to report the context of their transactive memory system, of the 23 systems; 7 were friends, 3 were family members and 13 were romantic partners.

Materials

The software was developed for the experiment in response to the lockdown and following restrictions imposed as a result of the Covid-19 outbreak in New Zealand. The experiment is available online at http://psychlab.massey.ac.nz:3000/. The contents of the software were designed as a conceptual replication and extension of Lawson's (2006) study.

The original survey was adapted and extended to allow for the replication of the original results while also investigating the IOU in transactive memory systems. The survey used for this research maintained the same structure as the original, beginning with the participants rating their functional knowledge of bicycles, then getting participants to complete the schematic drawing, then completing a multi-choice task and finally rerate their functional knowledge of bicycles. Each of these sections will be discussed with adaptations and extensions highlighted.

The first of the four major sections required participants to rate their functional knowledge of bicycles on a Likert scale from 1 ("I know little or nothing about how bicycles work") to 7 ("I have a thorough knowledge of how bicycles work"). The first question was a direct copy of the original Lawson (2006) experiment, with the following two questions as adaptations. These three questions were aimed at addressing different areas of transactive memory. The first question focused on individual knowledge, the second, the individual's partner's knowledge and the third, on the combined knowledge of the participant and their partner. These questions were coded for analysis as Q1, Q2, and Q3 respectively and provided pre-task ratings across the three questions.

In the second of the four sections, participants were required to complete two schematic drawings. The first section replicated the Lawson (2006) schematic drawing task which asked participants to, as best as they can, complete the schematic drawing of the main bits of the bicycle that were missing using the symbols provided. Participants required to complete the frame, pedals and chain of the bicycle using the key provided, as shown in Figure 1. The second schematic drawing task asked participants to work with their partner to collectively complete the same schematic drawing while communicating through a chat box. Errors that could be made in this section included but were not limited to three types of errors that would severely impact bicycle functioning. Examples of errors made in schematic drawings are seen in Appendix A.

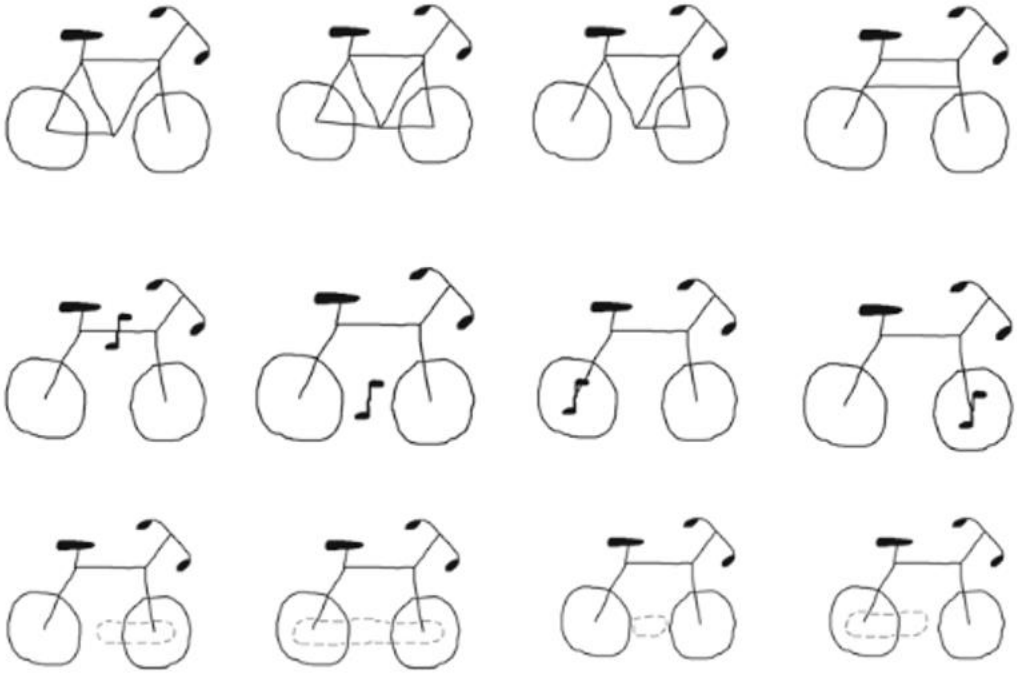
In the third of the four sections, participants completed a forced-choice task following the same structure as the original Lawson (2006) experiment. However, it was completed collaboratively again using the chatbox, rather than individually as seen in the original experiment. This section had three questions, all multichoice with four possible answers for each

question. The first gave options as to the correct position of the frame, second pedals (see Figure 3).

Figure 3.

Forced choice task options for frame, chain, and pedals.

Reproduced from "Lawson, R. (2006). The science of cycology: Failures to understand how everyday objects work [Original Paper]. Memory & Cognition, 34(8), 1667. https://doi.org/10.3758/bf03195929".



The fourth and final section required participants to rerate their functional knowledge of bicycles. This used the same questions, in the same order, as participants answered in the first section to give post-task ratings across the three questions. Answers to these questions were coded for analysis as Q4, Q5, and Q6 respectively.

As a result of participants completing the experiment in their own environments, all tasks were completed on privately owned computers or laptops. Participants were required to have a

device each and these devices were required to have access to a modern web browser and with a standard QWERTY keyboard and mouse or trackpad.

Procedure

All 23 originally recruited participants were requested to contact the researcher to arrange a time to complete the experiment and recruit a partner to complete the experiment with who would meet the participation criteria. All participants were provided with the link to the online experiment and reassured that this would work for both them and their partner. They were instructed to use the link to access the experiment during their allocated period. To complete the experiment, participants were required to follow the instructions presented for each section. Completion of the experiment required participants to answer all questions in the demographic and four main sections described above as well as follow up questions. To complete all sections of the experiment took between 10-15 minutes.

Once data collection had concluded, pairs whose responses or partners' responses met the exclusion criteria were discarded (N = 12).

The exclusion criteria are as follows. Either or both participants failing to complete the study. Free drawings completed either individually or collaboratively, that are unrelated to the task. Pairs that did not communicate in the collaborative drawing and forced-choice tasks in section two. Participants who do not meet the sample demographic requirements. Participants whose partner was excluded for any of the above reasons.

A software error had occurred early in the data collection process which resulted in individual and/or collaborative drawings not being recorded. This resulted in a further 8 responses being discarded. Once exclusion criteria had been satisfied and the data impacted by

the software error removed individuals whose partner had been removed were also removed (N = 2). The total number of participants excluded as a result was N = 22.

Results

Scoring and Analysis

The researcher scored and analysed the data using the Statistical Package for Social Scientists (SPSS, standard version 26, 2019). Drawing errors were scored using the same criteria as was used by Lawson (2006) with one point being assigned for each error. Descriptions of how error points are as follows:

"Frame errors: drawing the frame joining the front and back wheels, making steering impossible.

Pedal errors: failing to draw the pedals between the wheels and inside the chain so the pedals could not drive the chain (if the pedals were separated from the chain, or were omitted) or rendered the chain unnecessary (if the pedals were drawn attached to the centre of the front or back wheel). These errors often also meant that cyclists would find it difficult to reach the pedals with their feet.

Chain errors: failing to draw the chain around the pedals and the back wheel. In most errors, the chain was depicted looped around both the front wheel and the back wheel. This design would require the chain to stretch when the cyclist was steering." Lawson (2006, p. 1668).

Multichoice answers were also scored in the same way as Lawson (2006). The scoring method was as follows: "In the forced-choice task, the correct responses were first for the frame, second for the pedals, and fourth for the chain. All other responses were errors." Lawson (2006, p. 1668).

From the error scores and the pre- and post-task scores described above, three variables were created. The first of these was the individual difference score which used the first pre- and

post-task questions (Q1 - Q4). This is the individual difference score and showed if an IOU was present for individuals.

The second is the individual pre-task – post-task collaborative rating. It must, however, be noted that the author inadvertently specified in the pre-registration that the variable would be calculated by using the second pre-task question (Q2) and subtracting the second post-task question (Q5). These variables are focused on participants beliefs about their partners' knowledge of bicycles. When running analysis with the data it was identified that this was incorrect. The correction, after pre-registration, was made to instead use the first pre-task question (Q1) and the last post-task question (Q6) and correctly represent the required variable. The results of this represent a correction after pre-registration and therefore the following analysis was not fully pre-registered.

The third and final variable created was the collaborative error score. This was the sum of all errors made in the collaborate drawing and forced-choice task. As it was possible to score 3 errors in the collaborative drawing and another 3 in the forced-choice task, this resulted in a maximum collaborative error score of 6. If participants correctly completed the schematic drawing and correctly answered the forced-choice questions the score given was 0. As these results are collaborative, participants received the same score as their partner.

Main Findings

Table 1.

Average scores for the individual, partner, and collaborative scores (standard deviations are in parentheses).

Variable	Individual	Partner	Collaborative
Pre-task	4.74 (1.69)	4.98 (1.51)	5.33 (1.42)
Post-task	4.39 (1.82)	5.02 (1.68)	5.39 (1.34)
Drawing errors	1.00 (.99)	-	.76 (1.04)

Pre-registered Analyses

The first hypothesis predicted that individuals' pre-task ratings of their knowledge will be higher than their post-task ratings for individual task. The results of a paired samples, one-tailed, *t*-test provided support for this prediction, $t(45) = 2.27$, $p < .001$, $d_z = 0.34$, 95% CI [.04, .66]. Participants reported their pre-task knowledge as higher ($M = 4.74$, $SD = 1.69$) than their post-task knowledge ($M = 4.39$, $SD = 1.82$).

The second hypothesis predicted that individuals' pre-task ratings of their knowledge would be closer to the collaborative post-task ratings than to the individual post-task ratings. The participants reported their individual pre-task knowledge as higher than their individual post-task knowledge ($M = .35$, $SD = 1.04$) and their individual pre-task rating lower than their collaborative post-task rating ($M = -.65$, $SD = 1.39$). The results of a paired samples, one-tailed, *t*-test conducted with the difference scores calculated, although statistically significant, did not

provide support for this prediction, $t(45) = 5.36$, $p < .001$, $d_z = 0.79$, 95% CI [.62, 1.37]. The results instead showed that individuals underestimated their abilities as pairs, with their post-task collaborative ratings being higher than their pre-task individual ratings.

The third hypothesis predicted that the relationship between pre-task and post-task ratings would be stronger for the individual pre-task and collaborative post-task ratings than for the individual pre- and post-task ratings. The results of three one-tailed Pearson correlations, between individual pre-task and collaborative post-task ($r = .60$, $p < .001$), individual pre-task and individual post-task ($r = .83$, $p < .001$), and individual post-task and collaborative post-task ($r = .72$, $p < .001$) and a *z*-score calculated with Lee and Preacher (2013b) ($z = -3.26$, $p < .001$) did not provide support for this prediction. The results instead showed that the relationship between pre- and post-task ratings was stronger for the individual pre- and post-task ratings.

The fourth hypothesis predicted that the relationship between pre-task rating and performance (drawing) errors would be stronger for the individual pre-task rating and collaborative errors than for the individual pre-task ratings and individual performance errors. The results of six one-tailed Pearson correlations can be seen in Table 2. A *z*-score calculated with Lee and Preacher (2013a) ($z = -1.53$, $p = .062$) provided support for this prediction, however, this effect was not statistically significant.

Table 2.

Correlation Matrix for individual pre-task ratings, collaborative pre-task ratings, individual drawing errors and collaborative drawing errors.

Variable	1	2	3	4
1. Individual pre-task rating	-			
2. Collaborative pre-task rating	.83**	-		
3. Individual drawing errors	-.23	-.30*	-	
4. Collaborative drawing errors	.19	.047	.37**	-

Note. $n = 46$.

* $p < .05$.

** $p < .01$.

Pre-registered Exploratory Analyses

It is important to note that the following pre-registered exploratory hypotheses, the sample size may not be adequate to ensure sufficient power for these analyses.

The first pre-registered exploratory hypothesis predicted that pairs who had known each other for longer would do better on the collaborative task than pairs who had known each other for a shorter period of time. The results of a two-tailed Pearson correlation between relationship length and the total number of collaborative errors ($r = -.024$, $p = .88$) there was a very small correlation in the predicted direction between relationship length and the total number of collaborative errors but it did not meet statistical significance.

To investigate the second pre-registered exploratory hypothesis a moderator analysis was performed using PROCESS (Hayes, 2017). The outcome variable for analysis was collaborative task performance[2]. The predictor variable was pre-task individual ratings, this variable was inadvertently incorrectly specified by the researcher in the pre-registration syntax, therefore, the results of this represents a correction after pre-registration and therefore the following analysis was not fully pre-registered. This variable was also re-coded to assist in the interpretation of this analysis, but this was not made explicit in the pre-registration. The moderator variable evaluated for the analysis was relationship length. The interaction between pre-task individual ratings and relationship length was found to be non-significant [B = .026, 95% C.I. (-0.16, 0.21), p = .77] in this model, indicating that relationship length did not moderate the effect of pre-task individual ratings on collaborative task performance. The results of this analysis were found to be non-significant and can be seen in Table 3.

[2] Note that the measure of collaborative performance used in this analysis is different from that used in the other analyses as this measure uses that collaborative drawing errors and the collaborative multi-choice task errors.

Table 3.

Summary of Moderation Regression Analysis for Relationship Length Moderating the Relationship between Individual Pre-task Ratings and Collaborative Performance

Effect	Estimate	SE	95% CI		*p*
			LL	UL	
(Constant)	.83	0.64	-0.45	2.12	.20
Individual pre-task rating [a]	-.01	0.15	-0.32	0.30	.94
Relationship length [b]	-.12	0.37	-0.87	0.63	.75
Individual pre-task rating*Relationship length	.026	0.09	-0.16	0.21	.77

Note. $n = 46$.

[a] 0 = rating of 1, 1 = rating of 2, 2 = rating of 3, 3 = rating of 4, 4 = rating of 5, 5 = rating of 6, 6 = rating of 7.

[b] 0 = 3-30 months, 1= 31-60 months, 2= 61-144 months, 3 = 145+ months.

To investigate the third pre-registered exploratory hypothesis a moderator analysis was performed using PROCESS (Hayes, 2017). The outcome variable for analysis was post-task individual ratings. The predictor variable for the analysis was pre-task individual ratings. The moderator variable evaluated in the analysis was owning a bike. The moderator variable was correctly specified in the pre-registration; however, the incorrect syntax was inadvertently supplied by the researcher. Variables were also re-coded to assist in the interpretation of this

analysis, but this was not made explicit in the pre-registration. The results of this represent a correction after pre-registration and therefore the following analysis was not fully pre-registered. The interaction between pre-task individual rating and owning a bike was found to be non-significant [B = 0.087, 95% C.I. (-.30, .48), p = .065] in our model, indicating that owning a bike was a non-significant moderator on the effects of individual pre-task rating on individual post-task ratings. The results of this analysis were found to be non-significant and can be seen in Table 4.

Table 4.

Summary of Moderation Regression Analysis for Owning a Bike Moderating the Relationship between Individual Pre- and Post-task Ratings

Effect	Estimate	SE	95% CI		*p*
			LL	UL	
(Constant)	.20	0.48	-.75	1.17	.67
Individual pre-task rating [a]	.86	0.12	.62	1.09	<.001
Owning a bike [b]	-.39	0.79	-1.98	1.21	.63
Individual pre-task rating*Owning a bike	.087	0.19	-.30	0.48	.65

Note. n = 46.

[a] 0 = rating of 1, 1 = rating of 2, 2 = rating of 3, 3 = rating of 4, 4 = rating of 5, 5 = rating of 6, 6 = rating of 7.

[b] 0 = No, 1= Yes.

Further Exploratory Analyses

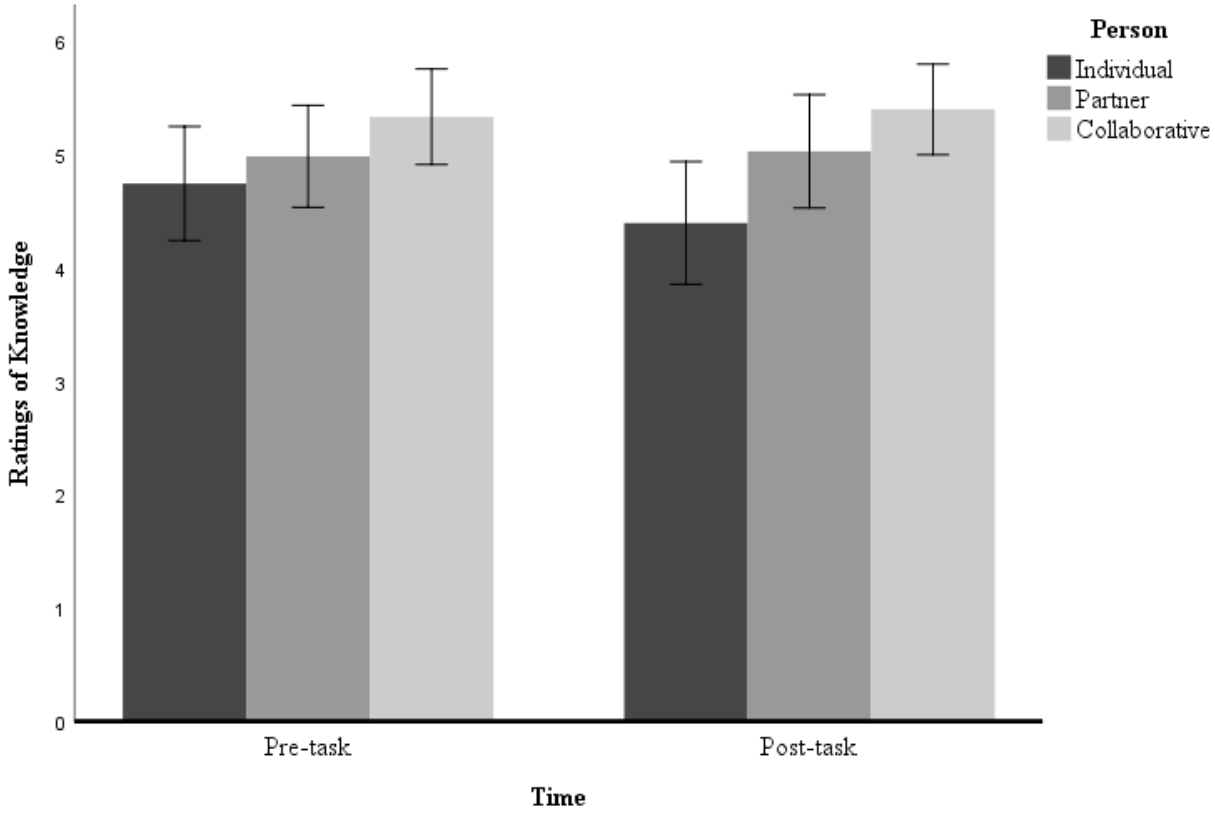
Further exploratory analyses were run, in addition to those specified in the pre-registration, to gain further insight into the results of the pre-registered analyses. It is important to note that the sample size may not be adequate to ensure sufficient power for these analyses.

Are there IOUs for partners and pairs as well as individuals?

A 2 x 3 factorial repeated measurers ANOVA was used to investigate the impact of time (pre- and post-task) on ratings of knowledge (self, partner and collaborative). The Shapiro-Wilk test statistic indicated that the assumption of normality was not supported; and Mauchly's test indicated that the assumption of sphericity was violated and therefore the Huynh-Feldt Epsilon adjusted tests were used. A significant main effect for time was not found F (1, 45) = .321, p = .574, partial η^2 = .007 with confidence levels pre-task ratings (M = 5.01, SD = 1.32) being higher than post-task ratings (M = 4.93, SD = 1.31). A significant main effect for rating was found, F(1.83, 82.34) = 7.15, p = .005, partial η^2 = .137, with individual ratings (M = 4.56, SD = 1.68) lower than partner ratings (M = 5.00, SD = 1.47) and lower than collaborative ratings (M = 5.36, SD = 1.26). Examination of the means indicated that although there was a large change in individual ratings pre-task (M = 4.74, SD = 1.69) to post-task individual ratings (M = 4.39, SD = 1.82), and partners' ratings pre-task (M = 4.98, SD = 1.51) to post-task partners' ratings (M = 5.02, SD = 1.68) although these changes were in different directions. However, there was very little change in collaborative pre- (M = 5.33, SD = 1.42) and post-task (M = 5.39, SD = 1.34) ratings. These results can be seen in Figure 5.

Figure 4.

Mean number correct (+SE) on pre- and post-task ratings of knowledge for individuals' (n = 46), partners' (n = 46), and collaborative (n = 46).



These results require replication to see if these are robust with an appropriately sized sample.

Differences between individual, partner and collaborative ratings of knowledge

Three paired samples, two-tailed, *t*-tests were run. The first assesses how accurately people could predict collaborative performance on the schematic drawing task. Although the results of this analysis were not significant, participants reported their pre-task knowledge as very slightly lower (M = 5.33, SD = 1.41) than their post-task knowledge (M = 5.39, SD = 1.34). This showed a slight change in people's predictions of their collaborative performance abilities,

this non-significant change suggests that individuals are assessing their collaborative performance accurately. The second investigated whether people thought their partners had the same level of knowledge as they did before tasks. Again, although the results of this analysis were not significant, participants reported their partners' knowledge as slightly higher (M = 4.98, SD = 1.51) than their own knowledge (M = 4.74, SD = 1.69). This non-significant change suggests that individuals are assuming that their partners' knowledge is the same as their own. The third explores whether people thought that collaboratively they would be more knowledgeable than on their own. Results of this analysis showed that individuals were predicting their collaborative knowledge (M = 5.33, SD = 1.42) would be greater than their individual knowledge (M = 4.74, SD = 1.69). Results for all three paired samples, two-tailed, t-tests can be seen in Table 5.

Table 5.

Summary of paired samples, two-tailed, t-tests showing Differences between individual, partner and collaborative ratings of knowledge

	M	SD	SE	95% CI		*t*	*p*	d_z
				LL	UL			
Pre-task Collaborative – Post-task Collaborative	-.065	1.11	.16	-.39	.26	-.40	.69	.054
Pre-task Individual – Pre-task Partner	-.24	1.75	.26	-.76	.282	-.925	.36	.14
Pre-task Individual – Pre-task Collaborative	-.587	.96	.14	-.87	-.30	-4.16	<.001	.62

Note. $n = 46$. df = 45

* $p < .05$.

** $p < .01$.

Relationship between subjective post-task ratings of task performance and task performance errors

A one-tailed Spearman's correlation was used to assess the relationship between individual post-task ratings and the individual number of errors. There was a significant correlation between the two, $r_s = -.29$, $p = .025$, $N = 46$. A second one-tailed Spearman's correlation was used to assess the relationship between combined post-task rating and

collaborative errors. There was a non-significant correlation between the two, $r_s = -.21$, $p = .085$, $N = 46$.

Discussion

The present study aimed to test the idea that IOUs are a consequence of our adaptation to the knowledge of objects possessed by a socially distributed cognitive system. It also responds to calls in both the knowledge illusion and transactive memory systems areas for further research on the IOU and if transactive memory systems help or hinder recall. Finally, it aimed to use these two areas of research to provide a deeper understanding of how members of small groups understand their individual and collective knowledge. In doing this, the intention was to assess the accuracy of an individual's ability to identify the limits of their knowledge in a transactive memory system.

As anticipated by the first hypothesis, individuals' pre-task ratings of their knowledge were higher than their post-task ratings of their knowledge. This finding shows an IOU in our study and replicates the findings of Lawson (2006) and Rozenblit and Keil (2002) where individual ratings of knowledge were higher before they completed the task than after they completed the task. Results suggest that after completing the task participants were required to make their implicit knowledge of bicycles explicit and were at this point confronted by their lack of knowledge which leads to lower post-task ratings than pre-task ratings. As a result, this suggests that the simple act of being required to make this implicit knowledge explicit is enough to ensure that individuals are aware of the gaps in their knowledge.

Unexpectedly, the second hypothesis, that individual pre-task ratings would be closer to post-task collaborative ratings than post-task individual ratings, was not supported. The results showed that pre-task judgements of individual knowledge were significantly lower than post-task judgements of collaborative performance. It was anticipated that individuals' pre-task ratings of their knowledge would be closer to the collaborative post-task ratings than to the individual post-

task ratings. These findings do not show anything about an IOU per se – rather it shows that the hypothesis was not supported. This hypothesis was created to test an idea about why an individual IOU happens. The results showed that people's individual estimates were lower than their collaborative post-task judgements because pre-task individual judgements aren't intended as an estimate of collaborative performance. That is, people are not making these individual judgements thinking they have anything to do with collaboration. These ratings are unable to help researchers *predict* the post-task collaborative judgement as it was thought it could.

The third hypothesis, that the correlation of individual pre-task and collaborative post-task ratings would be stronger than the correlation of individual pre- and post-task ratings, was also not supported. Others (e.g. Keil (2003); Mills and Keil (2004); Rozenblit and Keil (2002)) have suggested that IOUs occur because people's knowledge judgements are premised on our ability to access knowledge when we are embedded in knowledge communities. Thus, we predicted that people's individual pre-task ratings of their knowledge would demonstrate a stronger relationship with *collaborative* post-task judgements than with individual post-task judgements. It can be concluded that individuals are making poor judgements about their own knowledge and that individual knowledge judgements do not seem to be 'tacit' collaborative judgements. This does not necessarily mean that this hypothesis was wrong, perhaps the problem is that we were inappropriately treating two bicycle novices as a community of knowledge. In the present research we are using 'working with one person you have known for a minimum of three months' as a way of operationalising a community of knowledge. This is likely not a true representation of a community of knowledge in real life which will likely include individuals with expert knowledge and other resources such as books and the internet.

Future research could better operationalise a community of knowledge by ensuring there is access to the source of information within the knowledge community.

The fourth hypothesis, that the correlation between pre-task and performance (errors) would be stronger for individual pre-task ratings and collaborative performance than for individual pre-task ratings and individual performance, was not supported. The current results suggested that individual pre-task ratings better predicted individual drawing errors than collaborative drawing errors.

The results of the primary hypotheses raised a question around the appropriateness of the use of correlations in these analyses. In previous research, namely the work of Rozenblit and Keil (2002), correlations appear to have been used to imply that high correlations between pre-task ratings and post-task rating show that individuals are making more *accurate* judgements of their knowledge. This may not necessarily be the case. Correlations demonstrate the strength of the systematic variation between variables rather than a measure of accuracy. This creates a problem, where the correlations can not show how accurate participants are being when they are assessing their knowledge. While accurate judgements of performance *do* lead to high correlations, high correlations can also arise from *systematically* inaccurate judgements (e.g., where all participants overestimate their accuracy by the same amount). By contrast, a low correlation suggests there is no systematic relationship between judgements and performance, and thus that, on average, participants are not accurate judges of future performance.

Pre-registered exploratory hypotheses

The first pre-registered exploratory hypothesis predicted that pairs who had known each other for longer would do better on the collaborative task than pairs who had known each other

for a shorter period of time. The results of the experiment showed a slight decrease in the number of errors as relationship length increased, although this effect was not significant. This stands in contrast to earlier research done in the transactive memory field. It is worth considering that the overall task may have been showing a ceiling effect with the task not being sufficiently sensitive to show the benefit of collaborative recall. Work by Barnier et al. (2018), Giuliano and Wegner (1985), and Harris et al. (2011) all suggests that long term transactive memory systems are more likely to be constituted by individuals who cue one another and thus retrieve more information than transactive memory systems which had not existed for as long.

In contrast to the current study, and not considered in the original design of this study, is the body of research that investigates collaborative inhibition. Collaborative inhibition, where a group remembers less together than the members of nominal groups, has been discussed in the transactive memory literature since its conception. However, when the research was moved online in response to the Covid-19 pandemic and the resulting nationwide lockdown, the effects of collaborating in an online environment on the findings of the current study were not considered and the study was moved directly onto a digital platform. Research done investigating online collaboration has found that online-based collaboration, like that which was used in this research, results in high rates of collaborative inhibition (Hyman et al., 2013). Hyman et al. (2013) found that collaborative inhibition occurred most when there was a disruption of retrieval strategies, an example of this may have been when individuals were required to type their thoughts out in the current online study. As a result, it is reasonable to assume that collaborative inhibition arose as a result of the research being moved online, affected all of the pairs, and thus making it difficult to generalise about how participants might have performed if the research had been performed in person.

The second pre-registered exploratory hypothesis predicted that the relationship between individual pre-task ratings and collaborative performance would be moderated by the length of time individuals had known their partner. This was due to transactive memory systems strengthening and becoming more accurate as the length of time a transactive memory system has existed. Given it is probable that collaborative inhibition was at work in the current study, it is unsurprising that this hypothesis was not supported. The effect of collaborative inhibition on the results of the collaborative drawing task may have resulted in the drawing being completed primarily by one participant instead of it being completed as a team effort. Although not part of the planned analyses, a brief informal analysis of the chat that occurred while participants completed the task was conducted. This showed many of the pairs had one partner who took the lead in the task. In cases where an individual takes the lead, research shows collaborative inhibition is likely to occur (Basden et al., 1997; Wegner, 1987; Weldon & Bellinger, 1997). Three examples follow to illustrate the three common ways pairs started their communication in the chatbox. For many pairs, this set the tone for their collaboration or lack thereof.

1. In some cases, the lead role was delegated with comments as seen in this example. The communication in this example is open and collaborative, showing a willingness by both individuals to work together. The first participant asked, “We can only draw one at a time to get the best possible image… Do you want to start or shall I?” which was responded to with, “You!”.
2. In other cases, the lead role was ‘claimed”. This example shows the first message in the chatbox for this pair. One of the participants had started the task, taking the lead, before consulting with their partner. “What do you think is missing that is key?” The second person in the pair took the back seat only making suggestions.

3. A final example shows participants cueing each other, working together, and bouncing ideas off one another in a typical transactive memory style:

> P1: Want me to just give it a go?
>
> P2: The frame has me stumped; I cant remember where it goes. But I know the pedals are in the middle sooo yes please.
>
> P1: My computer is struggling with this...
>
> P2: I see that. Do you want me to try draw something?
>
> P1: Yes. You've seen what I'm trying to do.

These opening comments are setting the tone and roles and individual will play in collaboration through the drawing and multi-choice tasks. When conversations like this occur in person, it is possible to contextualise statements through tone of voice, delivery and nonverbal cues. However, when they are written in text, as they are in this experiment, it is harder for individuals to convey tone. Therefore, comments made by individuals may not be interpreted as they are intended. This can create a sense of ambiguity and make interacting more difficult and stressful for the pair which can also inhibit collaboration.

If collaborative inhibition was strong due to the experiment being facilitated online, this will change what is being investigated by this moderation. Making the assumption that a high level of collaborative inhibition is occurring, the collaborative performance rating may realistically be an individual performance score. If this is what is occurring, the moderation analysis is assessing if individual pre-task and individual performance are being moderated by the length of time individuals had known their partner. There is no reason for this moderation analysis to occur as relationship length is unlikely to be impacting individual ratings and performance. The effects of collaborative inhibition are unknown as well as the effect on the results of the analysis.

The third and final pre-registered exploratory analysis showed, contrary to our prediction, that the relationship between individual pre- and post-task ratings was not moderated by an individual's ability to ride a bike. This analysis intended to assess if people who can ride a bike might use that knowledge as a heuristic for working out whether they were knowledgeable about the workings of a bike. As this was an exploratory analysis these conclusions are tentative, and it would be useful to examine these relationships in the future with adequately powered studies.

Further Exploratory Analyses

Several non-pre-registered exploratory analyses were run to further understand the results of the pre-registered analyses. The most interesting results to come out of the further exploratory analyses were found in the results of the ANOVA of pre- and post-task ratings for individual, partners', and collaborative knowledge. The results highlighted a typical IOU for individuals and showed the result of partners' and collaborative pre- and post-task ratings and did not provide evidence for an IOU in partners' or collaborative knowledge.

In summary, individuals overestimate their individual knowledge, but not their partner's or pair's knowledge. Interestingly, people did not change their minds about their partner and collaborative ratings as they did for their individual ratings. This suggests they are thinking about their partner's knowledge and the pairs (transactive memory system) knowledge in a different way to their individual ratings. There are three possible reasons for the IOU not occurring for the partner and collaborative ratings. The first is that individuals have little or no useful information to guide their partner and collaborative ratings. If this is the case participants might be making pre-task judgements using potentially inaccurate and loose heuristics about partner and collaborative knowledge. Unless provided with evidence during the collaboration

task that ratings need to be different than at pre-task, individuals will likely make the same ratings in the post-task phase. An individual is unlikely to have ever asked their partner about how they believed their knowledge of bicycles would be rated on a scale of 1-7. Therefore, unless they know their partner is interested in, for example, cycling or mountain biking or they had little knowledge about bicycles, they will have little specific previous experience to draw on. In this situation, if their partner had gaps in their knowledge which came to light during the collaborative task, partner post-task ratings would have likely decreased. As, on average, people were rating their partners similarly. Any individual cases of ratings of partners' knowledge changing have been masked by the use of averages. Further analysis of the individual pairs' data for pre- and post-task ratings as well as the chatbox conversations might provide further insight into specific instances of ratings being adjusted and the cause of this.

The second possible explanation is that individuals *do* accurately rate their partner and collaborative knowledge at pre-task and therefore, have no reason for changing their mind for the post-task ratings. Research on the IOU suggests that individuals are unable to identify the limits of their own knowledge and identify what information is stored in their head (Justin & David, 1999; Keil, 2003; Mills & Keil, 2004; Zeveney & Marsh, 2016). However, the results of the current research suggest it is possible that individuals can recognise the limits of their partner's and collaborative knowledge. This suggests that we are better tuned to knowing and locating information in a transactive or collaborative context than as individuals.

A third potential explanation of the pattern of results is the individuals feel the pressure of providing socially desirable responses. When participants made pre-task ratings, they were not told that their partners were not going to be made aware of the ratings. When making these ratings, individuals might have been making ratings assuming that their partners were going to

see their ratings. To protect their relationships with their partners, individuals may have inflated their ratings, thus hiding any potential IOU.

The study did not provide conclusive results in favour of any of these possibilities. Further research is required to provide conclusive support one way or the other. These theories do provide a good springboard for future research.

Implications

As a result of this research being largely exploratory, the implications of the research are and will remain unclear until more research is conducted. This section aims to set out some of the possible practical applications of the research in the future.

There are numerous practical implications of the research to be considered. The lack of change between the pre- and post-task collaborative ratings shows one of two things: individuals are making accurate pre-task ratings or individuals have no points of reference for making these ratings. If collaborative ratings are more accurate than individual ratings, it may suggest that using collaborative teams, rather than relying on individuals, could mitigate problematic IOU-related actions. Having small transactive memory systems work collaboratively could result in groups that have a better understanding of their collective capabilities and thus being able to accurately identify if the situation they are in is beyond their capabilities.

The current study has also built on the work of previous research. It has strengthened the body of research suggesting that when individuals are asked to make their implicit knowledge explicit, they can identify the gaps in their knowledge. The practical applications of this include teaching. If teachers are aware of the IOU in their students, they may be able to more easily able to identify where the gaps in their students' knowledge. Identification of where gaps in

knowledge exist will enable teaching to be adapted so gaps in knowledge can be filled accurately.

There are also less novel practical implications such as when individuals' hold extreme political views. Previous research has shown that when people are questioned about their extreme views and asked to make them explicit, these are likely to soften and become less extreme (Alter et al., 2010). This could be taken beyond the political domain to investigate conspiracy theories and the like.

Research must also consider that Covid-19 has changed the ways people live, work and interact in ways impossible to imagine. More commonly than ever before teams are collaborating in online environments which may be hindering team's collaboration, producing less collaborative and more individualistic outcomes. There is potential for the ways we are communicating, and collaborating online, to evolve as more people collaborate in online environments, so the levels of collaborative inhibition and facilitation may change. Future research would need to factor this into decisions being made around research design as well as considering the value of in-person research in the future.

There is also the question of why people are not applying their own personal experience – of the task making them re-evaluate their own knowledge – to their partner's situation. People are not 'simulating' their partner's situations using their own experience, why is this occurring? In theory, this would be a very sensible thing to do, but the ratings are not suggesting this is happening. Future research could draw on the theory of mind research and theory (e.g., Goldman, 2006) to better understand why participants judge the knowledge of their partner differently from themselves.

Additionally, there is also a possible inconsistency in the way people are thinking about collaborative ratings. There are two reasons this inconsistency is interesting. One, if we think we (personally) are less knowledgeable than we thought, and two, if the team rating is some form of adding together how we rated ourselves and how we rated our partner, then we would expect collaborative post-task ratings to be lower than collaborative pre-task ratings. This isn't what was seen in the results, and people don't seem to be straightforwardly 'calculating' collaborative knowledge by adding together individual and partner knowledge info. It would be very interesting for future research to investigate if people are using some other kind of system for judging collaborative performance.

Shortcomings and Limitations

On reflection of the present research, there are several flaws which must be reflected on and explored (this is in addition to the shortcomings already discussed which include the implications of conducting collaborative research experiment online, the intricacies of using correlations in this type of research and sample size). These additional shortcomings and limitations include; sample, pre- and post-task predictions, learning and order effect, lack of counterbalancing and the use of averages in analyses. It is key to note that although some of these limitations were exacerbated by Covid-19 and the resulting lockdown which occurred, this is not the primary cause of many of these.

The sample is one factor that was exacerbated by Covid-19 and lockdown in New Zealand. As a result of the experiment being moved online, the population which was able and eligible to participate was restricted. Online research populations are biased as a result of their exclusivity. Typically, this type of research requires participants to have access to an appropriate

device as well as an internet connection, both are regularly required to be of high quality with the latest software. These requirements limit participants who can complete the experiment simply as they are unable to meet them, often expensive, requirements to participate. This frequently removes the demographics variable from the population that is found at the lower end of the socioeconomic scale. In-person research is less restricted by the eligible population as it does not typically require individuals to have access to individual devices and internet access, although this does not necessarily increase the demographic diversity of the sample. The effects of the experiment being conducted online on the current research are unknown.

There are numerous limitations of the predictions made by individuals as these are difficult to interpret and understand. Pre-task ratings are predictions made by individuals about how they believe they may perform; post-task ratings are predictions made by individuals about how they perceived their performance. Within the research, there is no simple way to assess the accuracy of either of these ratings compared to how individuals' performed in the task. No framework was developed which aligned, either through a tally system or another system, the ratings individuals produced with an expected number of errors. Therefore, it is impossible to assess the accuracy of the ratings individuals provide. This is not only a limitation for the individual ratings but the partner and collaborative ratings also. It limits the usefulness of the ratings in interpreting what is occurring for individuals while they are making these ratings. The development of a system or framework to align these ratings would allow for further interpretation of the correlations produced in the primary analyses.

The collaborative drawings were likely influenced by individuals' experiences from the individual drawing task. The implications of learning and order effects on the research were thoroughly considered during the design process. However, it was concluded that reversing the

order or counterbalancing of these tasks would have created more undesirable outcomes. Specifically, individuals would have simply repeated the collaborative drawings in the individual task, resulting in no truly individual drawings. The trade-off for this, it is expected learning effects will be seen in the collaborative results. The lack of counterbalancing to reduce the impact of learning is a clear limitation.

The use of means and averages when comparing pre- and post-tasks ratings needs to be considered further in future research. It would be useful to inspect the distribution of pre- and post-task rating distributions further to see if there are different identifiable types/classes of people or pairs, for example, pairs where the partner is known and where the partner is unknown. This would require a much larger sample.

Future Research

There is no doubt that future research in the area, investigating the IOU in small transactive memory systems, is needed. The current exploratory research only scratches the surface when it comes to understanding if the IOU exists in more than just individuals.

In-person replication of the experiment would provide much-needed insight into the possible effects of online inhibition of collaboration on the present research (Hyman et al., 2013). This would provide further data with which to reassess the current hypotheses and predictions. In doing this, if future research in the area is to continue being facilitated online, methods of both measuring and identifying if collaborative inhibition is occurring in pairs. Methods could utilise the chat function to conduct qualitative research to support further the exploration of collaborative inhibition in pairs. The conversations which accompany the completion of the collaborative tasks, whether in person or online, might also provide

information about the role's individuals assume in the collaborative task. Understanding these roles may provide further information about the roles which facilitated the occurrence of collaborative inhibition and IOU's in small transactive memory systems. Future research could investigate the relationship between the length of time the transactive memory system has existed alters the way transactive memory systems are functioning.

Future research could include timing individuals while they make pre- and post-task ratings. This may enable a further understanding of the cognitive processes at work when individuals make these judgements. For instance, if the time taken differs between individual, partners', and collaborative ratings. Comparisons could also be made with the speed of pre- and post-task ratings. Differences in the time taken to make ratings would show a more considered response. These more considered responses are more analytic and unlikely to be linked to an IOU. If post-task ratings are taking longer than pre-task ratings it may show that individuals are more analytic after the experience of doing the task and may help explain why post-task ratings are lower. A deeper understanding of these ratings could also pull in further ideas from the already existing literature.

As discussed previously, future research needs to critically reconsider the use of correlations of pre- and post-task ratings to understand how accurate ratings are in future analyses. Although these show relationships between variable, the information they provide do not provide information around the accuracy of the ratings being made rather only the strength of the relationships between them.

There would also be value in exploring methods of assessing if there is a transactive memory system in the pair and how strong the transactive memory system is. There are many possible advantages of developing and including a method of assessing the transactive memory

system in future research. Primarily, this would enable differences in ratings to be attributed to the confirmed, or not confirmed, existence of a transactive memory system or to another unknown factor.

Conclusion

Results of the analyses investigating the IOU in individuals supported the existence of an IOU in the current study. Although the results of the research were inconclusive for the existence of an IOU in the small transactive memory systems recruited for the study, the groundwork has been laid for future research in the area. Further research can focus on understanding how individuals are assessing their own knowledge and the knowledge they hold in their small transactive memory systems. Ultimately, there is potential for this research to impact how teams are formed and assigned in high stakes situations.

What has become increasingly apparent, is that several complex factors impact collaboration in small transactive memory systems. Unintentionally, it has also been highlighted that value of in-person collaboration protect from collaborative inhibition. In a practical sense, this highlights the importance of collaboration occurring in-person for future research and in real-life situations.

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Appendix A

Examples of Individual Schematic Drawing Errors from Participants

The above example shows frame and chain errors.

The above example shows frame, chain, and pedal errors.

The above example shows no frame, chain, or pedal errors.